AAAC Research Facilities

Researchers in the AAAC utilize a variety of experimental research facilities in the course of their activities. The list below presents the major facilities by AOE:

AOE 1: Fundamental Aerodynamics Technologies

- Basic Aerodynamic Research Tunnel
- 15-inch Low-Speed Tunnel
- 20 x 28 inch Shear Flow Facility
- 2 x 3-ft Boundary Layer Tunnel
- 20-inch Supersonic Wind Tunnel
- Supersonic Low-Disturbance Tunnel
- 7 x 11-inch Low-Speed Tunnel
- Probe Calibration Tunnel

AOE 2: Applied Aerodynamic Technologies

- 14x22 Subsonic Wind Tunnel
- NTF
- 0.3-Meter Transonic Cryogenic Tunnel
- Unitary Plan Wind Tunnel
- Jet Exit Test Facility

AOE 3: Acoustics Technologies

- Anechoic Noise Research Facility
- Jet Noise Laboratory
- Mobile Acoustics Capability
- Quiet Flow Facility
- Aircraft Interior Acoustic Simulator
- Flow Impedance Test Facility
- Thermal Acoustic Fatigue Apparatus
- Structural Acoustics Loads and Transmission Facility

AOE 4: Aerothermodynamic Technologies

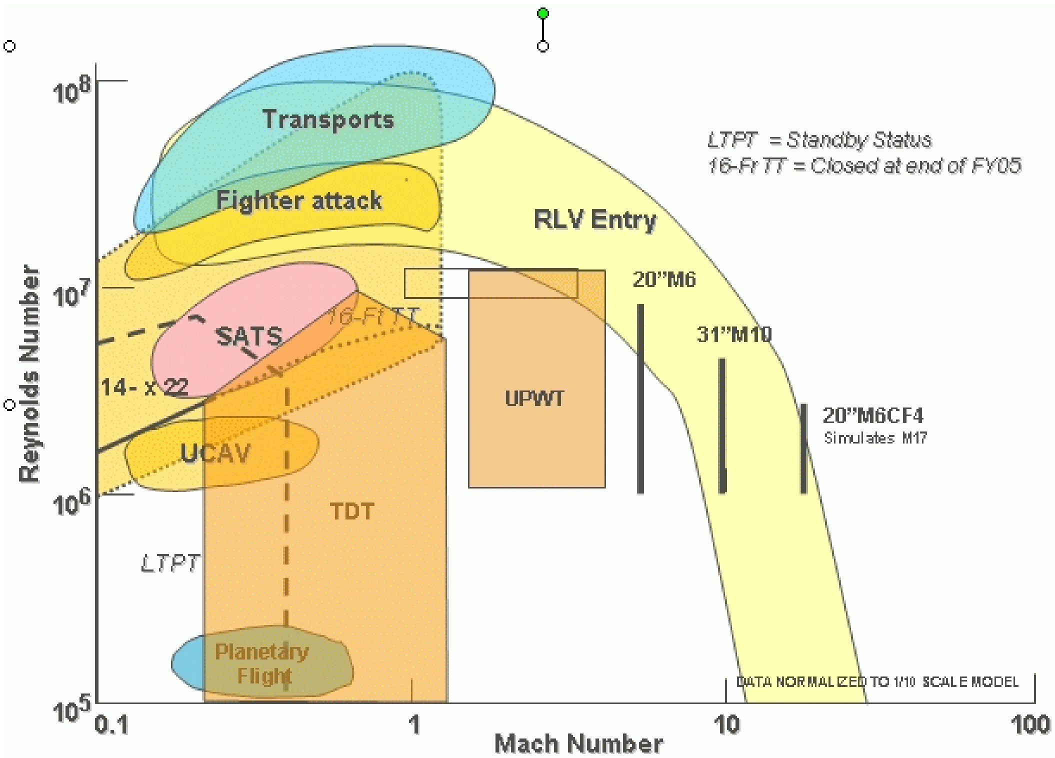
- 20-Inch Mach 6 Air Tunnel
- 20-Inch Mach 6 CF4 Tunnel
- 31-Inch Mach 10 Air Tunnel

AOE 5: Hypersonic Airbreathing Propulsion Technologies

- Arc-Heated Scramjet Test Facility (AHSTF)
- Combustion-Heated Scramjet Test Facility (CHSTF)
- Direct-Connect Supersonic Combustion Test Facility (DCSCTF)
- 8-Foot High-Temperature Tunnel (8-Ft. HTT)

- Hypersonic Pulse (HYPULSE) facility
- Mach 4 Blow Down Facility (M4BDF)

The accompanying figure illustrates the flight regime simulation capability made possible by this group of facilities. Brief descriptions of each of these major experimental facilities are given in Appendix B–Descriptions of Major AAAC Facilities and Laboratories.



Range of Wind Tunnels Required for Flight Vehicle Development

Fundamental Aerodynamics Technologies Facilities

Basic Aerodynamics Research Tunnel (BART)

The Langley Basic Aerodynamics Research Tunnel (BART) is located in Building 1214. The wind tunnel is a flow diagnostic facility dedicated to the task of acquiring data for code validation as well as investigating the fundamental character of complex flow fields. The BART is an open-return wind tunnel with a closed test section 28 inches high, 40 inches wide and 10 feet long. The maximum test section velocity is 185 feet per second which yields a unit Reynolds number of 1.13 million per foot. A honeycomb panel, four anti-turbulence screens, and an 11-to-1 contraction ratio condition the airflow entering the test section to produce streamwise turbulence intensities below 0.08 percent. Models are typically mounted on a post model-support system but the tunnel can be configured to mount models on the floor, sidewall, or ceiling.

Basic Aerodynamics Research Tunnel

The BART instrumentation and measurement techniques include 6-component internal strain gage balances, a five degree-of-freedom probe traverse system, an electronic scanning pressure system, a three-component hot wire, a three-component laser velocimeter, and a dynamic data acquisition system. The tunnel's 16 square feet of optical access on both sidewalls and the ceiling facilitate the use of several flow visualization techniques and advanced non-intrusive measurement techniques. These include Laser Velocimetry (LV), Doppler Global Velocimetry (DGV), Particle Imaging Velocimetry (PIV), and Pressure Sensitive Paint (PSP).

Characteristics:

- Test gas: Air
- Maximum Mach number: 0.17
- Test section size: 28 inches by 40 inches
- Test section length: 120 inches
- Contraction ration: 11.0/1.0

15-Inch Low-Speed Tunnel

The 15-Inch Low-Speed Tunnel is located in Building 1247B. The facility is a closed-loop tunnel capable of speeds up to about 130 f/s (40 m/s) with unit Reynolds number up to 0.9 million. The facility has many options to provide optical access for LV and PIV measurements.

15-Inch Low-Speed Tunnel

20 x 28-Inch Shear Flow Facility

The 20-Inch x 28-Inch Shear Flow Control Tunnel (20X28) is located in Building 1247D. The wind tunnel is a low speed open circuit facility used for basic boundary-layer research. The 20X28 is an open circuit low speed (150 ft/sec max) atmospheric facility with low freestream turbulence due to a series of screens and large contraction ratio settling chamber. The 20X28 test section is 15 feet long and has a cross section 20 inches high by 28 inches wide with an adjustable upper wall to control the pressure gradient over the long test section.

20 x 28-Inch Shear Flow Facility

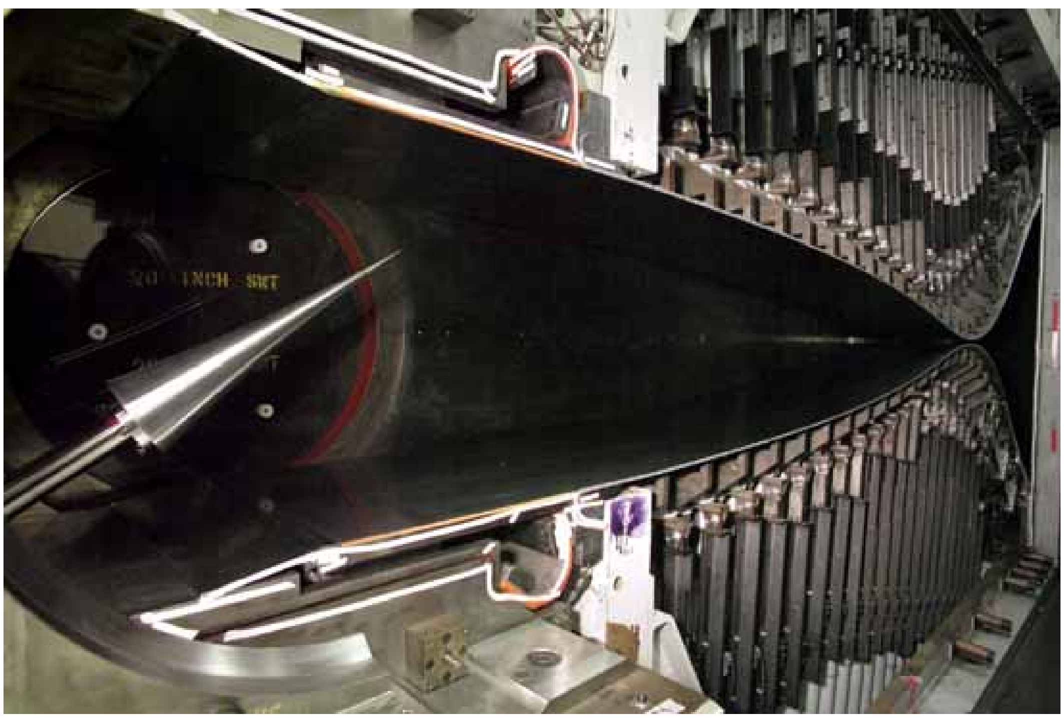
2 Foot by 3 Foot Low-Speed Wind Tunnel

The 2 Foot by 3 Foot Low-Speed Wind Tunnel is located in Building 1247H. The facility is a closed-loop tunnel capable of speeds up to about 148 ft/s (45 m/s) corresponding to a unit Reynolds number of 0.9 million per foot. The test section is 3 feet wide by 2 feet high by 20 feet long. The tunnel has a 10:1 contraction ratio. The turbulence-reduction devices upstream of the contraction consist of a honeycomb and four stainless-steel screens. The facility has low turbulence levels throughout the speed range making it ideal to do receptivity, flow instability and transition research. Measured turbulence intensities, u/U, are approximately 0.1% in the range of $0.1 < f < 400$Hz. The test-section foor and ceiling are adjustable to achieve a desired streamwise pressure gradient. Two motorized traverse stages, one with streamwise travel of 2.1m and the other with vertical travel of 150mm, are located just above the test section ceiling. The quoted accuracies of the streamwise (x) and vertical (y) traverse stages are ±166μm/m and ±30μm/m, respectively. A 3.8-cm streamwise slot (covered with rectangular wool felt strips to minimize air inflow/outflow along the centerline of the tunnel ceiling is provided to accommodate a probe support for 2-D traverse motion. Finally, the tunnel is equipped with acoustic drivers upstream and downstream of the test section to acoustically excite the flow as needed.

The 2 Foot by 3 Foot Low-Speed Wind Tunnel

20-Inch Supersonic Wind Tunnel (SWT)

The Langley 20-Inch Supersonic Wind Tunnel (SWT) is located in Building 1247D. The wind tunnel is a variable Mach number (M: 1.4 to 5.0) blowdown facility. The SWT has an 18-in.by 20-in. test section with optical access from the top and both sides. The SWT has a symmetric, two-dimensional, flexible wall nozzle, "quiet" valve and large (8-ft-diameter) settling chamber with extensive flow conditioners to provide a uniform test core. Models can be sting mounted on a unique model support system for heat transfer and force/moment testing with pitch ranging from–9.5° to 34° and +/-8.5° yaw range. Protection of models from startup and shutdown transient temperatures and loads is provided through a plenum isolation door and rapid injection/projection capability of the model support system. The facility operates over a wide range of stagnation pressures (0.5 to 130 PSIA) and temperatures (ambient to 200 F) with a maximum flow rate limit of 280 lb./sec. The tunnel can be operated subsonically up to Mach ~0.75 for low Reynolds number airfoil testing (+12° to -10° AOA) at Reynolds numbers per foot under 100,000. Instrumentation includes surface pressures and a fixed drag rake. The tunnel maximum dynamic pressure and Reynolds number per foot of 20 million are reached at Mach 2.88. A wide variety of measurement techniques can be used in the SWT including Laser Doppler Velocimetry.



Experimental Model Installed in the Supersonic Wind Tunnel (SWT)

Supersonic Low Disturbance Tunnel (SLDT)

The Supersonic Low Disturbance Tunnel (SLDT) is located in Building 1247D. The wind tunnel is a Mach 3.5 open jet blowdown facility developed for high speed laminar flow boundary layer stability studies. It has a maximum unit Reynolds number of approximately 2 million/inch. The jet exit is 6 inches high by 10 inches wide. Quiet flow is maintained by a combination of settling chamber free stream quieting features and a highly polished, rapid expansion, two-dimensional nozzle with an upstream bleed slot. The quiet test region is a rhombus spanning the nozzle and jet regions. The length of the rhombus varies with unit Reynolds number (inverse power law) from about 5 to 10 inches long. The maximum width is 7.5 inches and the height varies from 1.5 to 3.6 inches. Typical runtimes are in the range of 15-30 minutes. The primary use of the SLDT has been to provide experimental data for the development of linear stability theory for high speed flows.

Supersonic Low Disturbance Tunnel (SLDT)

7 x 11-Inch Low-Speed Facility

The 7x11 Inch Low Speed Tunnel is located in Building 1247D. The facility is an unpressurized, closed return air tunnel with a top speed of approximately 150 ft/sec and a free stream turbulence level of approximately 0.5% of the stream velocity. It has a 36 inch long test section with a 7x11 inch cross section. The test section is configured and optimized for direct drag measurements of flat wall panels. It employs a linear air bearing drag balance with additional provisions for streamwise pressure gradient control and panel gap leakage minimization. The tunnel also features provisions for various boundary layer diagnostics (pitot, hot-wire) and flow visualization (smoke injection, smoke-wire). The tunnel's primary usage has been for turbulent boundary layer drag reduction studies.

7x11 Inch Low Speed Tunnel

Probe Calibration Tunnel

The Langley (PCT) is located in Building 1247D. The facility is an open jet pressure tunnel with a capability to independently control velocity, density, and total temperature. The PCT has three interchangeable nozzles that give it a Mach number range of 0.05 to 3.5. Tunnel stagnation pressure and temperature can be varied from a minimum of 0.13 atmospheres to a maximum of 10 atmospheres and 460°R to 660°R respectively. This corresponds to a Reynolds number range of 0.47x106 < Re/ft< 57X106 for a Mach number of 1.

Probe Calibration Tunnel

Applied Aerodynamic Technologies Facilities

14’x22’ Subsonic Wind Tunnel

The 14’x22’ subsonic wind tunnel is located in Building 1212. The facility is a closed circuit, single return, subsonic-flow wind tunnel. Wind tunnel models can be tested using either a closed or open test section configuration. Previous models tested in the facility have included both high and low speed transports, a variety of rotorcraft configurations, high performance military vehicles, aerospace vehicles and lifting bodies, as well as powered lift models using high-pressure air. Additionally, this facility has been used to test for ground effect, free flight, dynamic oscillation, acoustic and extreme high angle-of-attack effects.

Characteristics:

- Test gas: Air
- Maximum closed test section velocity: 348 ft/sec
- Maximum open test section velocity: 283 ft/sec
- Reynolds number range: 0.0 to 2.2x106 /ft
- Test section size: 14.5 ft x 21.75 ft
- Test section length: 50 ft
- Drive power: 12,000 hp

National Transonic Facility

The NTF, located in building 1236, is a unique national facility that enables tests of aircraft configurations at conditions ranging from subsonic to low supersonic speeds at Reynolds numbers up to full-scale flight values, depending on the aircraft type and size. The facility is a fan-driven, closed circuit, continuous-flow, pressurized wind tunnel capable of operating in either dry air at warm temperatures or nitrogen from warm to cryogenic temperatures. The NTF is capable of an absolute pressure range from 15 psia to 125 psia, a temperature range from–320°F to 150°F, a Mach number range from 0.1 to 1.2, and a maximum Reynolds number of 146´106 per ft at Mach 1. Typical tests use a temperature range from -250°F to 120°F. Independent control of total temperature, pressure, and fan speed allow isolation and study of pure compressibility (Mach) effects, viscous (Reynolds number) effects, and aeroelastic (dynamic pressure) effect. Investigations include studies directed towards validation of advance design and analysis methods, improved ground-to-flight scaling methods, and development and assessment of advanced aerodynamic configurations and components at flight conditions.

National Transonic Facility

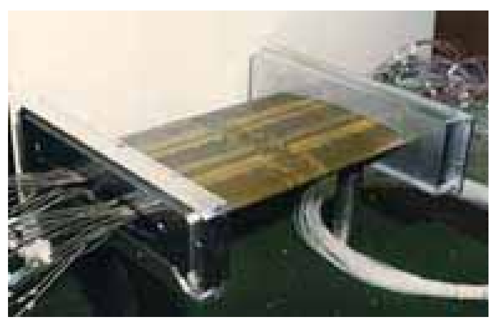
0.3-Meter Transonic Cryogenic Tunnel

The Langley 0.3-Meter Transonic Cryogenic Tunnel (0.3-M TCT) is located in Building 1242. The facility is used for testing two-dimensional airfoil sections and other models at high Reynolds numbers. The adaptive walls, floor and ceiling in the 13- by 13-in. (33- by 33-cm) test section can be moved to the free-stream streamline shape which eliminates or reduces wall effects on the model. The Mach number, pressure, temperature, and adaptive wall shapes are automatically controlled. The test section has computer-controlled angle-of-attack and traversing wake survey rake systems. Two inches of honeycomb and two anti-turbulence screens (total of five screens) have been added to the settling chamber. The contraction section has been replaced with a scaled version of the NTF contraction section. The normal test medium is gaseous nitrogen, GN2, which is injected as a cryogenic liquid. Up to 56,000 gallons of liquid nitrogen, LN2, can be stored in on-site tanks, which are refilled either by truck or directly by pipeline from a nearby manufacturing plant. The facility can also use air or a heavy gas (sulfur hexafluoride, SF6), with a restricted test envelope, as the test medium. Air and SF6 are used only at ambient temperature and require the use of a heat exchanger.

Characteristics:

- Mach number range: 0.2 to 0.9
- Reynolds number: 1 x 106 to 100 x 106 / ft
- Pressure range: 14.7 to 88.0 psia
- Temperature range: 320 to 130 degrees F

0.3 Meter Transonic Cryogenic Tunnel



Typical Airfoil Model

Unitary Plan Wind Tunnel

The Langley Unitary Plan Wind Tunnel (UPWT) is located in Buildings 1251A-E. The facility is a closed-circuit, continuous-flow, variable-density supersonic wind tunnel with two test sections: one with a design Mach number range from 1.5 to 2.9 and the other with a Mach number range from 2.3 to 4.6. The tunnel is equipped with asymmetric sliding-block-type nozzles for varying the ratio of nozzle throat to test section area, thus providing continuous variation in Mach number during facility operation. The low and high Mach number test sections are formed by the downstream contours of each nozzle. Test sections are nominally 4-ft by 4-ft in cross section by 7-ft in length. The maximum Reynolds number per foot varies from 6 x 106 to 11 x 106, depending on Mach number and test section.

The major elements of the facility are the 100,000 hp drive system, 6 centrifugal compressors operated in varying combinations or modes, dry air supply, evacuating system, cooling system, and inter-connecting ducting which produce the desired run conditions through either of the two test sections. The tunnel duct circuit can be circumscribed by a rectangle 263 ft by 210 ft.

Characteristics:

- Mach number range: 1.5 to 4.6
- Reynolds number per ft: 0.5 x 106 to 11.0 x 106
- Pressure: 0 to 10 atmospheres
- Temperature: 125 to 175 degrees F
- Test section size: 4 x 4 x 7 ft

Test Section of the Unitary Plan Wind Tunnel with Sting-Mounted Model

Jet Exit Test Facility (JETF)

The Langley Jet Exit Test Facility (JetF) is located in Building 1234. The facility is an indoor nozzle test stand which combines multiple-flow air propulsion simulation with high-pressure and high-mass-flow capabilities. Two individually controlled 1800-psiA air lines supply the test model system(s) and provide flow rates up to 23 lbm per sec. Supply air is heated to maintain room-temperature conditions at critical model measurement stations. Pressurized air from one or both supply lines is directed through a selected model interface system into the propulsion simulation geometry, and vented to atmosphere in the large test bay area. Exhaust flow is drawn outside the facility through two roof-mounted ventilation systems, keeping the test bay conditions at atmospheric pressure.

Two model support systems are available for testing. The dual-flow propulsion simulation system is designed for supply and control of two separate flow fields: a primary (core) flow and a secondary flow. It incorporates a 6-component strain-gage force-and-moment balance with maximum axial force capacity of 1200 lbf. A nozzle installed to this rig can be tested at charging-station total pressures up 350 psi and total temperatures up to 90 degrees F. Such conditions provide nozzle pressure ratios in excess of 20, simulating static conditions for supersonic flight. An alternate test rig, which does not incorporate a balance system, is also available. It is a simple plenum chamber that mixes high-pressure air from both sources to supply a single intake for larger scale models.

Instrumentation:

- Temperatures
- Mass-flow measurements
- Shadowgraph

Counter Flow Thrust Vectoring Nozzle Concept in the JETF

Combined Core and Fan Exhaust Configurations

Acoustics Technologies Facilities

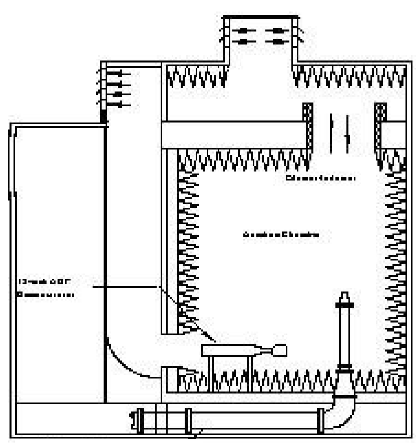
Anechoic Noise Research Facility (ANRF)

The Anechoic Noise Research Facility (ANRF) is located in Building 1218A. The facility is an open circuit, high-pressure air driven anechoic wind tunnel. The anechoic chamber measures 27.5' x 27' x 24' from the tips of the acoustic wedges. The acoustic wedges, which cover the walls, floor and ceiling, are 3' in depth and provide 99% sound absorption at frequencies above 125 Hz. The chamber can be accessed by soundproof doors both at ground level and on the second floor of the building.

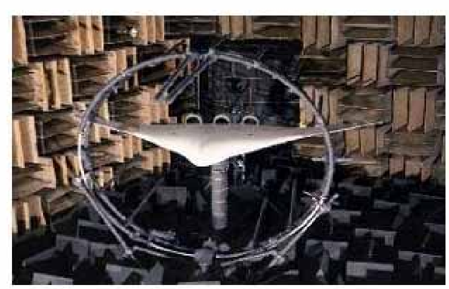
The ANRF can be operated in one of two modes, Mode I jet flow or Mode II air turbine flow. When the air system is configured in Mode I operation, the ANRF is a low-speed anechoic wind tunnel. Mode I operation is a vertical flow path through the anechoic chamber. When the facility is configured in Mode II operation the 600 psi supply air is used to drive the 1000 HP, four-stage air turbine of the high power 12-inch Advanced Ducted Propeller (ADP) engine Demonstrator. The 12-inch ADP Demonstrator is a research tool that is used to investigate the fan noise generation mechanisms of high bypass ratio aircraft engines.

Characteristics:

- Two mode operation: Jet flow and air turbine flow
- 27.5’ x 27’ x 24’ inside wedges
- 99% absorption above 125 Hz
- 255 psig air, 10 lbm/sec
- Nacelle aeroacoustic models:
    - 12” high-powered fan
    - 12” low-powered fan



Plan View of Anechoic Noise Research Facility



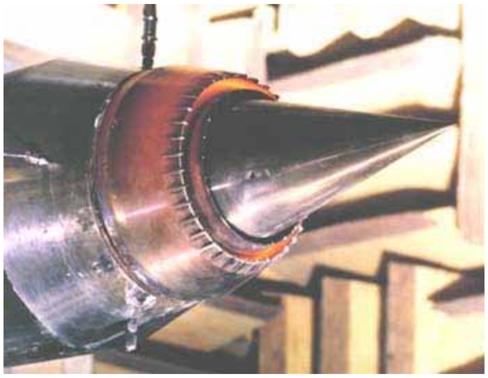
Model of Blended Wing Body airframe in the ANRF for noise shielding evaluation

Jet Noise Laboratory

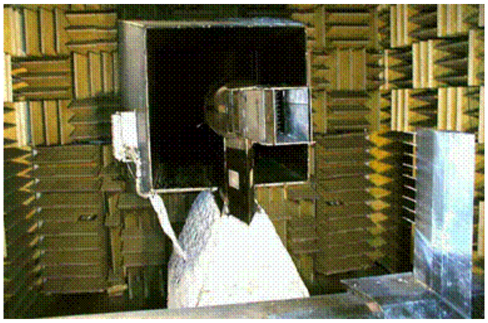
The Jet Noise Lab is located in Building 1221A and contains a Small Anechoic Jet Facility (SAJF) and the Low Speed Aeroacoustic Wind Tunnel (LSAWT). The Lab is used to conduct research aimed at understanding, predicting, and controlling exhaust noise from turbofan and turbojet engines. A dual-stream jet engine simulator (JES), capable of replicating the exhaust conditions of any existing or contemplated turbofan engine, is mounted in the LSAWT. To simulate forward velocity, the JES is surrounded by a square free-jet inside a large anechoic room. Flow measurement/visualization capability includes particle image velocimetry, sharp-focused Schlieren, and imaging radiometry. The SAJF consists of a small single-stream jet inside a 10’ x 12’ x 8’ anechoic chamber. Research emphasis is on the fluid mechanics and acoustics of jets. Objectives of the research are to understand the noise generation process, to develop methods for predicting flow fields and their associated noise, and to identify and demonstrate noise reduction and control techniques.

Characteristics:

- Low Speed Aeroacoustic Wind Tunnel
  - Continuous flow, free-jet
  - Dimensions: 4.7 ft. X 4.7 ft.
  - Mach No.: 0.1 to 0.32
  - Anechoic chamber cutoff frequency: 200 Hz.
- Jet Engine Simulator
  - Dual stream mass flow: 15 lbm/s per stream
  - Nozzle pressure ratio: ~10
  - Total nozzle pressure: ~ q150psia
  - Total temperature: 100 to 2000 deg. F
- Small Anechoic Jet Simulator
  - Single stream mass flow: 2lbm/sec
  - Nozzle pressure ratio: ~8
  - Total temperature: 100 to 350 deg. F
  - Anechoic chamber cutoff frequency: 200 Hz.
- Flow measurement/visualization
  - Particle image velocimetry
  - Sharp-focused Schlieren
  - Imaging radiome



Dual-stream Jet Engine Simulator with Co-annular Nozzle Installed.



Jet Engine Simulator and Model in Free-Jet Flow of the LSAWT.

Mobile Acoustic Facility

The Langley Mobile Acoustic Facility (MAF) is used to acquire ground based noise measurements. This system is typically used to measure aircraft noise; however, it can be used to acquire acoustic data for practically any type of noise source. The MAF is a multi-component capability which consists of the Digital Acoustic Measurement System (DAMS), the Remote Acquisition and Storage System (RASS), a tethered weather balloon system, a 10 meter weather profiler, and a Differential Global Position System (DGPS) based tracking and guidance system, as well as multiple data reduction and analysis computers.

The DAMS consists of 3 instrumentation data vans that can each operate up to 10 microphone systems. Data from the analog microphone system are digitized in a box located approximately 6 feet from the microphone. The digital data are then sent to the data van by wire, where the data from all microphone systems are merged and recorded on magnetic disk. The RASS system consists of 10 self-contained microphone systems that can be deployed at remote locations. Data from the analog microphone system are digitized in a box located approximately 6 feet from the microphone. However, with the RASS system the acoustic data are recorded on magnetic media located at the microphone location. Additional features of the MAF are: the tethered weather balloon system, which consists of an electric winch-controlled, tethered, helium-filled balloon, an instrumentation and telemetry pod, a ground-based receiver/data-controller, and a ground-based support computer; the 10-meter weather profiler which consists of a 10-meter tower with 10 temperature sensors, five anemometers, and three wind direction sensors; and the DGPS which measures the vehicle location as a function of time so that the relative location of the noise source to the receiver (microphone) is always known.

DAMS instrumentation data van

RASS microphone system

Quiet Flow Facility (QFF)

The Quiet Flow Facility (QFF) at the NASA Langley Research Center is located in Building 1208. The QFF is an anechoic open-jet facility, designed specifically for acoustic testing. The anechoic chamber surrounding the free jet has dimensions of 9.1 m x 6.1 m x 7.6 m high as measured from acoustic wedge tip to wedge tip. The free jet exhausts vertically through an acoustically treated exhaust port in the chamber ceiling. Flow-circuit turbulence screens and turning vanes have been included to ensure low turbulence airflow. The entire anechoic room is mounted on springs to isolate it structurally from the rest of the building to minimize transmission of structure-borne noise into the facility.

Characteristics:

- 20 ft x 30 ft x 24 ft inside wedges
- 0.995 absorption above 70 Hz
- Vertical free jet
- 2 ft x 3 ft nozzle
- Mach number up to 0.17

Instrumentation:

- Small Aperture Directional Array
- 2D array of 1/8 inch microphones
- 8 inch max separation
- 33 elements

Test setup for an airframe component noise study

Aircraft Interior Acoustic Simulator

The Aircraft Interior Acoustic Simulator (AIAS) is located in Building 1208. The AIAS facility was built to study human response to aircraft interior noise. It uses the interior trim and seats from current commercial airplanes to provide the visual ambience of a modern aircraft interior. The simulator is approximately 24 feet long and 11.5 feet wide and provides tourist class seating for up to 45 passengers. Noise stimuli for subjective judgment tests are presented to the test subjects through electrostatic headphones to preserve the directivity and spatial information afforded by a binaural recording system. Up to six listening stations are available. The recordings presented to test subjects are made using a binaural recording mannequin, which uses microphones located in each ear of a simulated head to record sounds as heard by an individual, and a DAT recorder. Recordings are downloaded to a workstation and digitally processed with commercial editing and analysis software. Software developed in house is used to play the sounds in the required sequence over the headphones to the test subjects

The headphone reproduction can be supplemented by 24 loudspeakers situated in the walls of the simulator outside the trim, and by further loudspeakers placed at the rear of the simulator to enhance the low frequency content of the sound in the facility. For example, three woofers and a subwoofer were used in addition to binaural headphone playback for rotorcraft interior noise simulation.

Test Subjects in Simulator

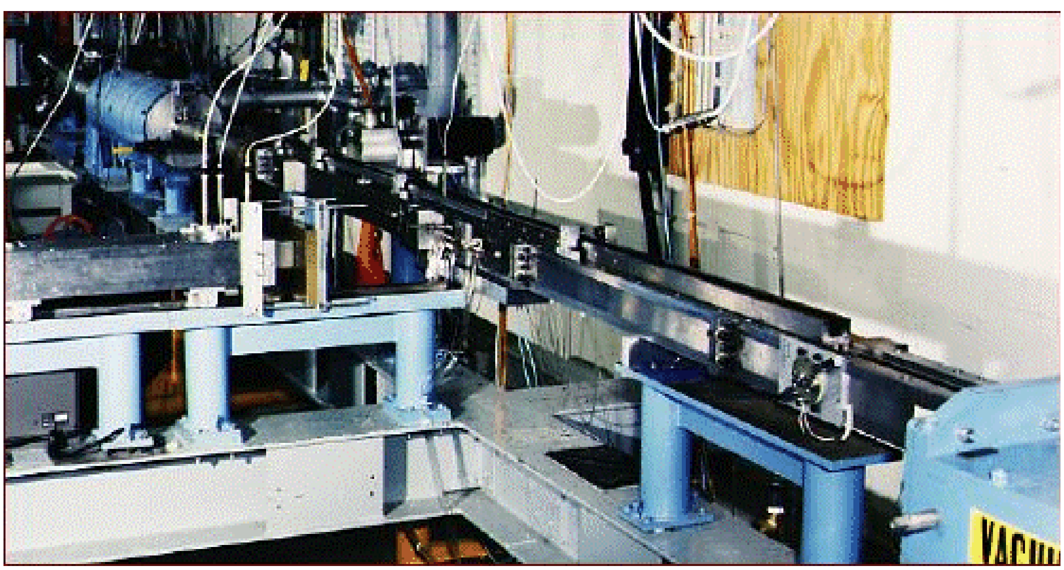
Binaural Recording Mannequin

Flow Impedance Test Facility (FITF)

The Flow Impedance Test Facility (FITF) is located in Building 1287. The facility is used to characterize the acoustic performance of full-scale acoustic liner materials for use in commercial aircraft engine nacelles. The FITF contains four major measurement apparatuses. The first is a raylometer, which is used to measure the DC flow resistance of acoustic absorbers. This fully automated device is currently capable of measurements over a velocity range of 0.001 to 5 meters/sec, which is well beyond the range of raylometers commonly used in industry. The second apparatus is a pulse impedance tube, in which a time-domain approach is used to determine the acoustic characteristics of test samples at high sound pressure levels. This is achieved via a high intensity sound source, capable of producing pulses up to 170 dB.

The third apparatus is a 2"x2" normal incidence impedance tube. Sound waves are impinged onto the surface of acoustic absorbers mounted onto the end of this apparatus. This sound is reflected from the sample, setting up standing wave patterns that are used to determine the absorptive qualities of the absorbers. The last, and most significant, apparatus is a grazing flow impedance tube. This 2"x2" cross-section wind tunnel is used to measure the acoustic properties of sound absorption materials in the presence of mean flow up to Mach 0.5. The normal incidence and grazing incidence tubes are typically operated over a frequency range of 500 to 3000 Hz, with incident sound pressure levels ranging from 100 to 160 dB (maximum level is test specimen dependent).

The data acquired in the Flow Impedance Test Facility is often used to assess the validity of the data acquired by the industry labs. Improved techniques for the measurement and prediction of noise reduction in aircraft engines using modern acoustic liners have been developed.



Grazing Flow Impedance Tube

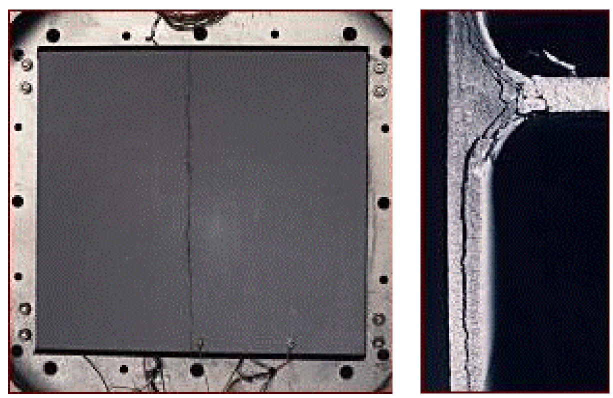
Thermal Acoustic Fatigue Apparatus (TAFA)

The Thermal Acoustic Fatigue Apparatus (TAFA) is located in Building 1221A. The TAFA, a progressive wave tube test facility, is used to test structures for dynamic response and sonic fatigue due to combined, high-intensity thermal acoustic environments. Prior to 1994, it was used to support development of the thermal protection system for the Space Shuttle and the National Aerospace Plane, and various generic hypersonic vehicle structures.

Extensive modifications to the sound generation system and to the wave tube itself were made in 1994 and 1995 to improve the facility's performance. Since these improvements, it has been used for sonic fatigue studies of the wing strake subcomponents on the High Speed Civil Transport. In 2000, enhancements were made to the acoustic control system to provide an automated means of shaping of a wide variety of spectrum shapes in a fast and efficient manner. As a result, acoustic control was improved in spectrum shaping ability, test section coherence, the addition of multiple inputs to the control, and the time required to attain control. Also, a new closed-loop temperature controller and thermocouple data acquisition system was developed to replace the previous system.

These improvements make possible the generation of a wide variety of test spectra, including blast or transient loadings. The facility has a frequency range of 40 to 500 Hz and an OASPL range of 126 to 172 dB. A 360 kW quartz lamp heating system provides radiant heat with a peak heat flux of 54 W/cm2.

TAFA Facility

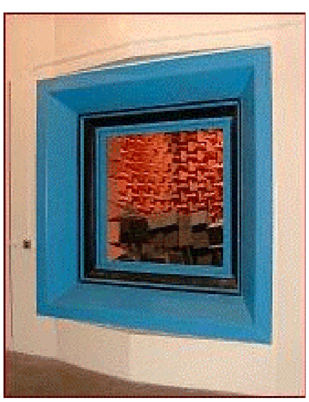


Acoustic Fatigue Damage to Carbon-Carbon Test Articles

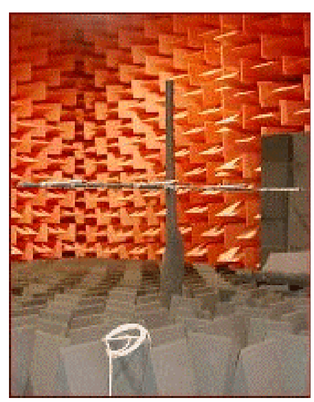
Structural Acoustic Loads and Transmission (SALT) Facility

The Structural Acoustic Loads and Transmission (SALT) facility is located in Building 1208. The facility consists of an anechoic chamber, a reverberation chamber, and a transmission loss (TL) window. The anechoic chamber is 4.57-m high, 7.65-m wide and 9.63-m long, measured from wedge tip to wedge tip for a volume of 337 cubic meters. The double walls of the chamber (concrete and sheet rock) were designed to provide 54 dB of sound attenuation at 125 Hz. Two 0.21-m thick, 1.65-m wide and 3.13-m high swinging door assemblies, with reinforced metal facings and interior absorptive materials provide access to the room. More than 4850 open-cell, polyurethane acoustic wedges cover the walls, the ceiling and the floor in the anechoic chamber. The 0.914-m tall wedges have a 0.3048-m by 0.3048-m by 0.3048-m base with a 0.610-m long, tapered section for a weight of 1.69 kg per specimen. Absorption coefficients range from 1.19 at 100 Hz to 2.80 at 5000 Hz. The movable partition in front of the TL window is covered with an arrangement of 90 wedges. An hemi-anechoic environment can be obtained by removing the wedges from the floor of the anechoic chamber. The anechoic and hemi-anechoic chambers provide a free-field or a partly free-field environment for sound power, sound pressure level, sound intensity and directivity measurements of acoustic sources.

The 278 cubic meters reverberation chamber is structurally isolated from the rest of the building and measures approximately 4.5 m by 6.5 m by 9.5 m. The chamber walls and ceiling are splayed to diminish the effects of standing waves between opposite surfaces and are separated by a 30-inch air gap from the surrounding 0.46-m thick concrete building walls. The total surface area of the walls, floor and ceiling is approximately 290 meters squared. The TL window accommodates 1.41-m by 1.41-m test structures to allow for sound radiation and sound transmission loss measurements. The TL window frame was installed on four isolators in the wall of the reverberation chamber. A rubber slab connecting the reverberation and anechoic chambers is used to prevent the transmission of structural vibrations into the anechoic chamber. Concrete supports with steel fairings and multiple layers of lead provide high noise attenuation.



Transmission Loss Window from Reverberation and Anechoic Chamber Sides



Typical Microphone Array

Aerothermodynamic Technologies Facilities

20-Inch Mach 6 Air Tunnel

The 20-Inch Mach 6 Tunnel is located in Building 1247D. The wind tunnel is a versatile, workhorse hypersonic facility, which is utilized for aerodynamic and aeroheating testing of advanced access to space and planetary vehicles and exploring basic fluid dynamic phenomena including boundary layer transition. The facility is ideally suited for both parametric and benchmark aerodynamic, aerothermodynamic and fluid dynamic studies. The synergism of this tunnel with the Langley 31-Inch Mach 10 Air Tunnel allows assessment of compressibility effects at constant Reynolds number and ratio of specific heats, gamma. Also, synergism with the 20-Inch Mach 6 CF4 Tunnel allows the experimental determination of real gas aerodynamic effects at constant Mach number and Reynolds number.

Characteristics:

- Test Gas: Dry Air
- Stagnation Pressure (psi): 30 to 475
- Stagnation Temperature (R): 760 to 940
- Mach number: 6
- Reynolds number, per foot: 0.5 to 8.0 x106/ft
- Dynamic Pressure (psi): 0.51 to 7.6
- Shock Density Ratio: 5.3
- Test Core Size (in): 12 by 12
- Max. Run Time (sec): 900
- 10 Runs per Day

Instrumentation:

- Phosphor Thermography
- Surface Oil-flow
- Thin Film Heat Transfer Gages
- Schlieren
- Force and Moment
- Pressures

20 Inch Mach 6 Air Tunnel

20-Inch Mach 6 CF4 Tunnel

The 20-Inch Mach 6 Tunnel is located in Building 1275. The tunnel is a versatile, workhorse hypersonic facility, which is utilized for aerodynamic and aeroheating testing of advanced access to space and planetary vehicles and exploring basic fluid dynamic phenomena including boundary layer transition. The 20-Inch Mach 6 Tunnel is the only operational, conventional-type hypersonic facility in this country that simulates dissociative real-gas phenomena associated with hypersonic flight

Furthermore, synergism with 20-Inch Mach 6 Air Tunnel allows determination of real gas aerodynamic effects at constant Mach number and Reynolds number.

Characteristics:

- Test Gas: Tetraflouromethane
- Stagnation Pressure (psi): 100 to 2000
- Stagnation Temperature (R): 1100 to 1480
- Mach number: 6
- Reynolds number, per foot: 0.05 to 0.75 x106/ft
- Dynamic Pressure (psi): 0.09 to 1.6
- Shock Density Ratio: 11.8
- Test Core Size (in): 14 (dia)
- Max. Run Time (sec): 30
- 4-6 Runs per Day

Instrumentation:

- Phosphor Thermography
- Surface Oil-flow
- Thin Film Heat Transfer Gages
- Schlieren
- Force and Moment
- Pressures

20-Inch Mach 6 CF4 Tunnel

31-Inch Mach 10 Air Tunnel

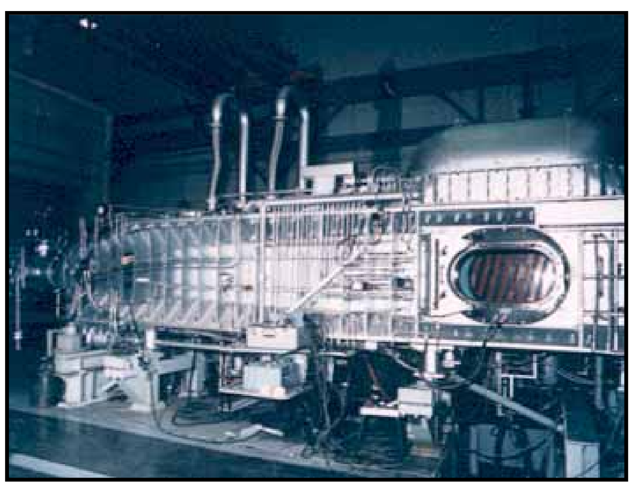
The 31-Inch Mach 10 Tunnel is located in Building 1251A. The tunnel is a hypersonic facility that possesses a large temperature driver that is ideal for heat transfer studies. With its extremely uniform flow quality, it is considered to be excellent for CFD code calibration experiments as well as aerodynamic performance testing. The 31-Inch Mach 10 Tunnel features a uniform, clean flow and includes a three-dimensional, contoured, water-cooled nozzle and five micron particle filter to remove flow contaminates. The facility is ideally suited for both parametric and benchmark aerodynamic, aerothermodynamic and fluid dynamic studies. Also, synergism with the Langley 20-Inch Mach 6 Air Tunnel allows assessment of compressibility effects at constant Reynolds number and ratio of specific heats, gamma.

Characteristics:

- Test Gas: Dry Air
- Stagnation Pressure (psi): 150 to 1450
- Stagnation Temperature (R): 1850
- Mach number: 10
- Reynolds number, per foot: 0.2 to 2.2 x106/ft
- Dynamic Pressure (psi): 0.65 to 2.4
- Shock Density Ratio: 6.0
- Test Core Size (in): 14 by 14
- Max. Run Time (sec): 120
- 10 Runs per Day

Instrumentation:

- Phosphor Thermography
- Surface Oil-flow
- Thin Film Heat Transfer Gages
- Schlieren
- Force and Moment
- Pressures



31-Inch Mach 10 Air Tunnel

Hypersonic Airbreathing Propulsion Technologies Facilities

Arc-Heated Scramjet Test Facility (AHSTF)

The NASA Langley Arc-Heated Scramjet Test Facility (AHSTF), located in Building 1247B, has historically been used to test complete (inlet, combustor, and partial nozzle), subscale, scramjet component integration models. A Linde electric-arc heater is used to heat dry air to produce stagnation enthalpies duplicating that of flight at Mach numbers ranging from 4.7 to 8. This heating process results in a test gas containing small amounts of nitric oxide. Gaseous hydrogen (at ambient temperature) is used as the primary fuel in the scramjet engines tested in the AHSTF. A 20/80-percent mixture of silane/hydrogen (by volume) is available for use in the scramjet model as an ignitor/pilot gas to aid in the combustion of the primary fuel.

Characteristics:

- Test Gas: Electric-arc-heated air
- Simulated Flight Mach Number: 4.7 to 8
- Stagnation Temperature (degrees R): 2000 to 5200
- Stagnation Pressure (psia): 660 maximum
- Simulated Flight Dynamic Pressure (psf): 150 to 1200
- Reynolds Number (per foot): 3.5 x 104 to 2.2 x 106
- Nozzle Exit Mach Number: 4.7 and 6.0
- Nozzle Exit Area (inches): 11.17 x11.17 (M=4.7); 10.89 x10.89 (M=6.0)
- Maximum Run Time (seconds): 30(M=8) to 60 (M=4.7)
- Runs per day: 4 to 6

Instrumentation:

- Six-component force balance
- Pressure
- Temperature
- Heat transfer
- Schlieren

Arc-Heated Scramjet Test Facility (AHSTF)

Combustion Heated Scramjet Test Facility (CHSTF)

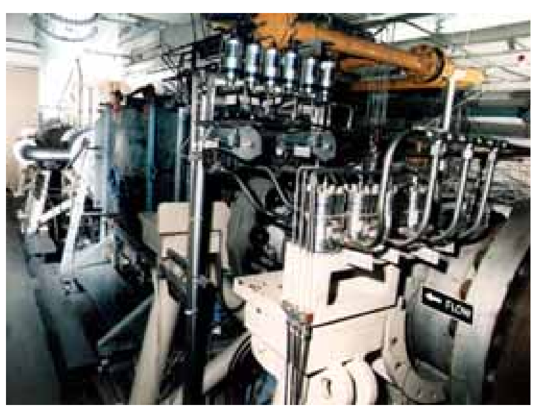
The NASA Langley Combustion Heated Scramjet Test Facility (CHSTF), located in Building 1221D, has historically been used to test complete (inlet, combustor, and partial nozzle) subscale scramjet component integration models. The facility uses a hydrogen and air heater capable of producing stagnation enthalpies duplicating that of flight at Mach numbers ranging from 3.5 to 6. Oxygen is replenished in the heater to obtain a test gas with the oxygen mole fraction of air (0.2095). Either gaseous hydrogen or gaseous ethylene (both at ambient temperature) may be used as the primary fuel in the scramjet engines tested in the CHSTF. A 20/80-percent mixture of silane/hydrogen (by volume) is available for use in the scramjet model as an ignitor/pilot gas to aid in the combustion of the primary fuel.

Characteristics:

- Test Gas: Hydrogen-air combustion products with oxygen replenishment
- Simulated Flight Mach Number: 3.5 to 6
- Stagnation Temperature (degrees R): 1300 to 3000
- Stagnation Pressure (psia): 50 to 500
- Simulated Flight Dynamic Pressure (psf): 250 to 3500
- Reynolds Number (per foot): 1.0 x 106 to 6.8 x 106
- Nozzle Exit Mach Number: 3.5 and 4.7
- Nozzle Exit Area (inches): 13.26 by 13.26
- Maximum Run Time (seconds): 30
- Runs per day: 5 to 10

Instrumentation:

- Six-component force balance
- Pressure
- Temperature
- Heat transfer
- Surface oil-flow
- Schlieren



Combustion Heated Scramjet Test Facility (CHSTF)

Direct-Connect Supersonic Combustion Test Facility (DCSCTF)

The NASA Langley Direct-Connect Supersonic Combustion Test Facility (DCSCTF) is located in a 16- by 16- by 52-ft test cell within Building 1221D. The facility has historically been used to test ramjet and scramjet combustor models at stagnation enthalpies duplicating that of flight at Mach numbers between 3.5 and 7.5. Data acquired using the facility is typically used to assess the mixing, ignition, flameholding, and combustion characteristics of ramjet or scramjet combustor models. A hydrogen-air combustion heater is used to produce the required high enthalpy test gas; oxygen is replenished in the heater to obtain a test gas with the same molar oxygen content as standard air, 0.2095. Various fuels may be supplied to the ramjet or scramjet combustor models including gaseous hydrogen, gaseous hydrocarbons, and heated liquid hydrocarbons. A new liquid fuel heater is available that can supply heated JP-7 fuel at maximum conditions of 1200 F, 1000 psia, and 0.75 pps. A 20/80-percent mixture of silane/hydrogen (by volume) is available for use in the model as an ignition source for the primary fuel.

Characteristics:

- Test Gas: Hydrogen-air combustion products with oxygen replenishment
- Stagnation Pressure (psia): 115 to 500
- Stagnation Temperature (degrees R): 1300 to 3800
- Simulated Flight Mach Number: 3.5 to 7.5
- Nozzle Exit Mach Number: 1.7, 2.0, and 2.7
- Nozzle Exit Area (inches): 1.52 by 3.46 and 1.50 by 6.69
- Reynolds Number (per foot): 2.0 x 106 to 8.0 x 106
- Maximum Run Time (seconds): 60
- Runs per day: 5 to 20

Instrumentation:

- Pressure, temperature, and heat transfer
- Schlieren/shadowgraph
- Coherent Anti-stokes Raman Spectroscopy (CARS)

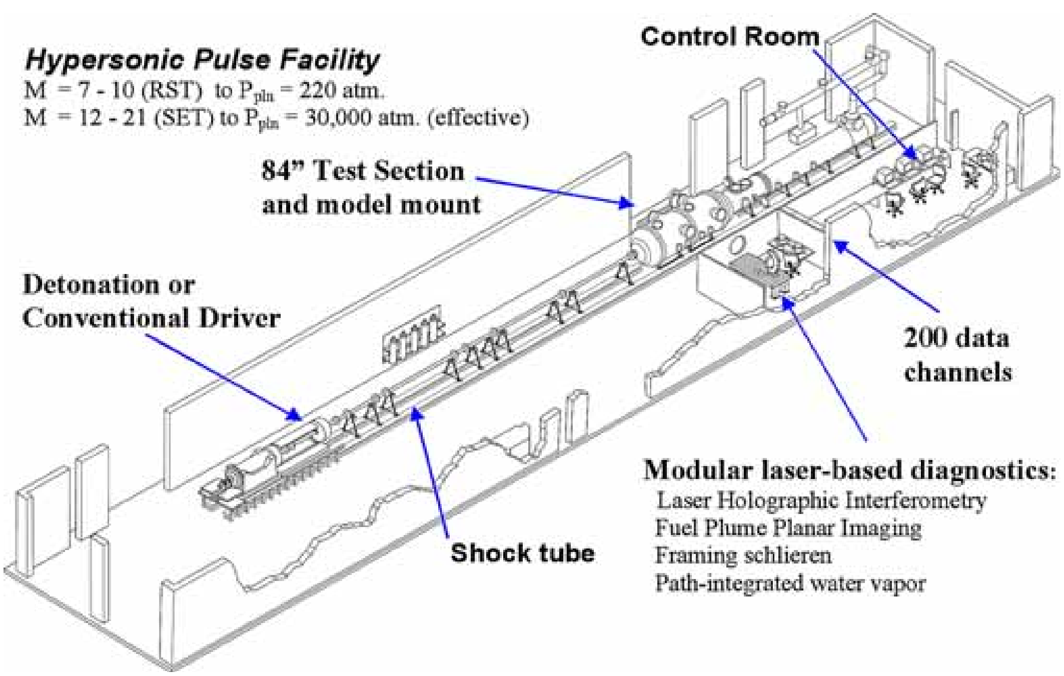
Direct-Connect Supersonic Combustion Test Facility (DCSCTF)

Hypersonic Pulse (HYPULSE) Facility

The HYPULSE test facility is a dual-mode shock tube/tunnel that is located at and operated by ATK-GASL in Ronkonkoma, NY under contract to the NASA Langley Research Center. The facility can be configured as a reflected-shock tunnel (RST) for duplication of atmospheric flight speeds up to Mach 10 or as a shock-expansion tunnel (SET) for duplication of conditions into the hypervelocity flight regime from Mach 12 to near orbital. In the RST mode, the facility has been used to obtain data for scramjet fuel injectors and combustors and, most recently, the development and evaluation of the Mach 10 engine flowpath of the X-43A (Hyper-X). In the SET mode, the facility provides the test capability for aerothermodynamics studies of aeroheating and planetary re-entry in the hypervelocity regime. Recent research has established a usable scramjet test capability in the Mach 12 to 15 range, with HYPULSE in the SET configuration. Characteristics of the dual-mode operation are listed and the major components are identified in the schematic.

Characteristics:

Configuration	RST mode	SET mode
Test gas	air (custom)	air or planet atmosphere
Test Regime		
Flight Mach	7 to 10+	12 to orbital
Dynamic pressure (psf)	1500 to 600	up to 2000 (for scramjet)
Test times (ms)	3 to 7	0.5 to 2
Dimensions (length, ft)		
Driver (w detonation)	8 (27.15)	8 (32.8)
Shock tube	54.5	17.25
Acceleration tube	----	41.4
Test section (/w dump tank)	19 (49)	19 (49)
Nozzles exit dia. (area ratio)	2.188 (AR225)	1.5 (AR9)



Mach 4 Blowdown Facility (M4BDF)

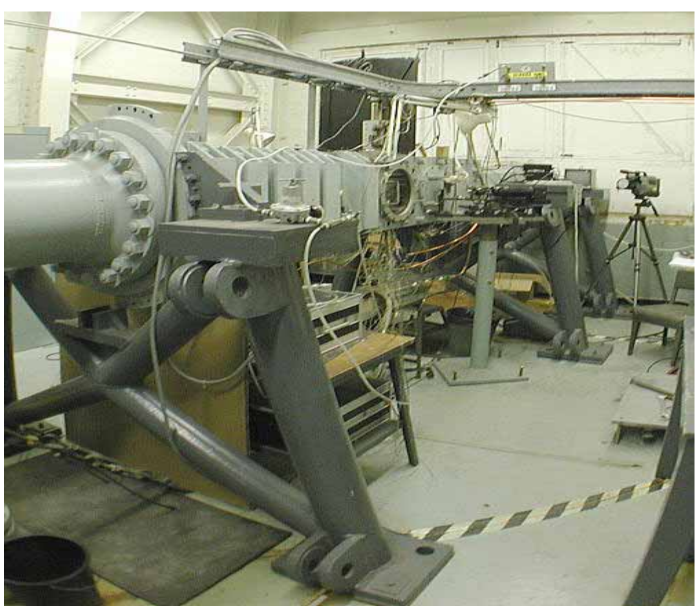
The Mach 4 Blowdown Facility is located in Building 1221C. The facility is used for the screening of hypersonic and supersonic inlets that would be further developed in other research facilities. Probe calibration tests and other research activities that require Mach 4 test conditions are also conducted. The two-dimensional facility nozzle expands into a 9" x 9" square test section. A plate, that spans the test section, can be installed near the front of the test section at one of several vertical positions to provide a simulated forebody boundary layer entering an inlet. A 2.00" wide by 2.75" high rectangular flowmeter is frequently used to measure air mass capture, provide backpressure, and to unstart inlet models during tests. Inlet models up to 3 feet in length that block up to 20% of the flow area have been tested in the facility.

Characteristics:

- Test Gas: Dry Air
- Stagnation Pressure (psia): 175 to 250
- Stagnation Temperature (R): 500 to 540
- Mach number: 4.0
- Reynolds number, per foot: 16 to 23 x 106
- Test Core Size (in): 7 x 7
- Run time: Continuous
- 10 Runs per Day

Instrumentation:

- Pressures 128 @ 1 Hz; 8 @10 KHz
- Schlieren
- Surface oil flow



Mach 4 Blowdown Facility (M4BDF)

8-Foot High Temperature Tunnel

The Langley 8-Foot High Temperature Tunnel (8-Ft. HTT) is located in Buildings 1265 and 1265A-G. The facility duplicates true total enthalpy at hypersonic flight conditions for testing advanced large-scale, flight-weight aero-thermal, structural, and propulsion concepts. The 8-Ft. HTT is a methane/air combustion-heated hypersonic blow-down facility with vacuum for altitude simulation provided by an air ejector. Oxygen is replenished in the test gas for air-breathing propulsion tests to achieve the standard atmospheric mole fraction of oxygen. The facility provides simulation of flight conditions at Mach numbers of 4, 5, and 7 through a range of altitudes from 47,000 to 120,000 feet. The 26-foot diameter test section, which contains the 8-foot diameter by 12-foot long flow test flow space, will accommodate very large models, air-breathing hypersonic propulsion systems, and structural and thermal protection system components. Additional simulation capabilities are provided by a radiant heater system that can be used to simulate ascent or entry heating profiles. Typical test duration is approximately 60 seconds.

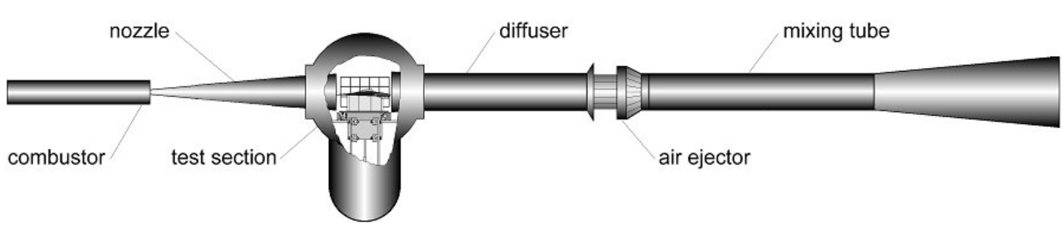
Characteristics:

Mach Number	**4**	**5**	**7**
Stagnation Pressure, psia*	50 to 310	90 to 530	600 to 3500
Stagnation Temperature, R	1640	2350	2500 to 3650
Dynamic Pressure, psf	525 to 3100	350 to 2000	320 to 1900
Reynolds Number, 10^6/ft	0.87 to 5.09	0.44 to 2.58	0.3 to 3.0
Altitude Simulation, k-ft	47 to 85	65 to 100	80 to 120
Heating Rate, BTU/ft$^{1.5}$-sec	7.0 to 17	10.5 to 25.3	20 to 48

*Stagnation pressure with oxygen replenishment is limited to 2000 psia.

Instrumentation:

- Six-component force balance
- Pressure (standard and high-frequency)
- Temperature
- Heat Transfer
- Schlieren
- Accelerometers
- Radiometers



Artist concept of the 8-Foot High Temperature Tunnel